BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: The Meteorological and Aeronomical Aspects of Planetary Encounter Missions: I. Mars
Case 233

DATE: July 17, 1967

FROM: M. Liwshitz

ABSTRACT

The manned planetary encounter missions envisioned for the late 1970's embrace the study of all aspects of the planetary environment. This paper deals with the meteorological and aeronomical phases of a manned Martian encounter mission. Present knowledge of the Martian atmosphere is briefly surveyed, and its effect on the mission is analyzed. The remainder of this paper is devoted to a concise but comprehensive description of atmospheric experiments included in such a mission. It is concluded that the complement of probes and sensors foreseen for such a mission offers the opportunity to obtain a rather complete knowledge of the Martian atmospheric structure and the dynamic processes occurring in it.

(NASA-CR-154794) THE METEOROLOGICAL AND AERONOMICAL ASPECTS OF PLANETARY ENCOUNTER MISSIONS. 1: MARS (Bellcomm, Inc.) 26 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

Despite centuries of planetary astronomy and highly accurate knowledge of planetary motions, near ignorance still prevails with respect to the physical conditions in the immediate vicinity of the planets, with the obvious exception of the Earth. Factual information about the atmospheric environment, even of the minor planets, is scant and subject to conflicting interpretations. This is basically a consequence of the low resolution inherent in observations carried out from distances on the order of an astronomical unit, and the lack of opportunity in the past to verify the interpretation of remote observations directly by the results of measurements with in situ probes.

Against this background it becomes clear that the early full scale planetary missions can be expected to yield a prodigious enhancement of man's knowledge of the planets' atmospheric environment, provided the study of the planets' atmospheric environment is approached in a systematic manner.

The remainder of this report is devoted to this particular aspect of an early Martian encounter mission. After surveying briefly the present knowledge of the Martian atmosphere and touching on some phases of the encounter mission affected by extant information, this report deals mainly with the integration of atmospheric studies into the overall mission plan. The latter is geared mainly to the retrieval of surface soil samples for possible detection of planetary biota, and to the acquisition of a copious amount of surface photographs needed for the next stage in planetary exploration, i.e., manned landings.[1] Nonetheless, this constraint still leaves ample opportunity for the investigation of phenomena allied with the Martian atmosphere, capable of yielding sufficient data for a fairly complete reconstruction of this planet's atmospheric environment.

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II. BIRD'S EYE VIEW OF THE STATUS OF KNOWLEDGE ON THE MARTIAN ATMOSPHERE

To obtain a global model of a planet's atmosphere it is necessary to gather a representative sample of its structural parameters, such as temperature, partial and total pressures and density, as well as information about the dynamic processes in the atmosphere, such as general circulation and the interaction of the atmosphere with solar radiation. The present paucity of firm atmospheric data on Mars is best illustrated in Figure 1, which shows in a schematic way the wide gap between extant data on temperature and neutral gas density in the Martian atmosphere, and a modest estimate of data requirements for a first realistic global model of this atmosphere. The large prisms represent this estimated quantity of data points, each point being represented by a small cube. Coordinates at the base denote schematically latitude (λ) and longitude, or time of day (t). SP denotes southern polar regions, SM southern middle latitudes, E equatorial regions, and NM and NP refer to the northern hemisphere. M, N, E, NT refer respectively to morning, noon, evening, and night. The vertical coordinates refer to regions of altitude (not necessarily equally spaced), spanning the range from ground level to a few hundred km. The different heights of the respective figures for T and ρ indicate that data requirements may differ for the various parameters considered. The shaded cubes represent available data; the degree of shading corresponds to the reliability of data.

The temperature data implicit in Figure 1 are those obtained with earth-based bolometry in 1954[(2)] (the lightly shaded cubes) and the temperature profiles of the atmosphere below ~30 km above the points of immersion and emersion, deduced from the Mariner IV RF occultation experiment in 1965[(3)] (darkly shaded). The density data were also deduced from the latter experiment.

These data and their counterparts on air pressure, in addition to the electron density profile above the point of immersion, exhaust the present store of reliable Martian atmospheric structural data. While Figure 1 represents schematically the extent of available data, their quantitative content is represented in Figures 2-4.

Figure 2 shows the neutral gas density profile below 30 km, and the electron density profile in the ionosphere, which are the most direct deductions from the results of the Mariner IV occultation experiment. To extend the model over the unknown region between these two disparate sets of data, theoretical interpretation has to be resorted to. This results in the widely differing models for the temperature and density profiles of the Martian atmospheres, Figures 3 and 4. A fuller discussion of the Mariner IV occultation experiments may be found elsewhere.(4)(5)

The composition of the Martian atmosphere is known only to the extent that its constituents are accessible to earth-based spectroscopic identification. This excludes two a priori likely candidates, nitrogen and argon, which may constitute a sizeable fraction of the Martian atmosphere, but lack suitable spectroscopic features. Of the major constituents, CO_2 has been identified and its approximate quantity has been established at ~ 10 g/cm^{-2}. The presence of $\sim 10^{-3} - 10^{-2}$ gm/cm^{-2} water vapor has also been detected.

Though motions of various types of clouds have been observed in the Martian atmosphere, no firm statements can be made about the atmospheric circulation on Mars. However, the surmised large amplitude of diurnal and seasonal variations in surface temperature suggests the possibility of circulation patterns which may significantly differ from the terrestrial one.

III. EFFECTS OF THE MARTIAN ATMOSPHERE ON THE ENCOUNTER MISSION PROFILE

The very tenuousness of the Martian atmosphere, indicated by the results of the Mariner IV occultation experiment, alters the entry conditions of any vehicle impacting on Mars, as compared to, say, impact on the Earth or Venus. The presence of a residual atmosphere suggests, on the other hand, that aerodynamic effects cannot be neglected altogether, as is the case in lunar missions.

To assess the extent to which knowledge (or ignorance) of the Martian atmosphere affects some phases of a 1975 Martian encounter mission, some knowledge of the overall mission profile and the complement of probes envisioned for the mission is pertinent.(1) Figure 5 illustrates the proposed system pictorially, showing the planet and the various probes, which are represented by symbolic figures with Roman numerals.

I represents the manned encounter vehicle (MEV) scheduled to pass by Mars in 1975 in an almost rectilinear orbit at a velocity of about 10 km/sec, approaching the planet's surface within about 300 km. II represents the small (∿200 lbs total weight) aero-drag probes to be launched from the MEV for early (∿1/2 day before the MEV's arrival at periapsis) impact on the planet. III is an orbiting probe, similar to the Lunar Orbiter, whose main task is a long term (∿1 year) photographic survey of the planet's surface. IV is the Martian Surface Sample Return (MSSR) vehicle, designed mainly for acquisition of a small soil sample at the surface and return of the same to the manned vehicle. It also carries a small weather station and geophysical package to the surface, designed to operate for ∿2 years after the date of the MEV passage. Similarly, long term monitoring of local weather and soil conditions is the function of the soft lander, or landers V_a and V_b. To obtain coverage of a wider variety of environmental conditions, the landers should be emplaced in the polar region or in an equatorial region antipodal to the MSSR site (which is restricted to low latitudes in the current mission plan).

Deployment of this variety of probes with different physical and operational characteristics presents a wide spectrum of technological problems associated with the various phases of entry into the planet's atmosphere and landing on the surface, while maintaining a communication link with the MEV or Earth for the better part of this period. A summary of these problem areas and the proposed solutions are given in Table I. Some of these items will now be discussed in more detail.

The utility of the drag probe data is contingent on a near vertical trajectory of the probe from entry into the atmosphere to the ground. But in the tenuous Martian atmosphere vertical entry delays effective aerodynamic deceleration to relatively low altitudes, such that during the greater portion of its descent the probe is in virtual communications blackout. Figure 6 offers some insight into this problem. It can be seen that for a minimum of ∿10 sec communication time under the constraint of near vertical entry, the upper limit on the ballistic coefficient of the probe is about 0.15 slugs ft^{-2}. A small drag probe with suitable characteristics is now under development for launch from advanced Mariner and Voyager vehicles[6], and has been tested successfully in free fall in the Earth's atmosphere. Unless atmospheric data from unmanned missions in the near future preclude the use of this module with minor modifications in a 1975 encounter mission,* it may virtually be taken off the shelf. If, on the other hand, this particular design proves unfeasible, major modifications should not pose serious problems. Considerable research seems to be underway in this direction.[7]

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*This mission is characterized by a high (∿28,000 fps) hyperbolic excess velocity at Mars, which accentuates the problems of deceleration and communication blackout.

Two main effects of the atmosphere on the operational profile of the orbiter have to be considered. The first is deboost of the orbiter into a low circular orbit around Mars, ∿300 km above the planet. This is evidently the best way for utilization of the orbiter in its main function as a long lived photographic monitor of the planet's surface. This entails, however, a velocity change of ∿22,000 fps for insertion from the 1975 encounter trajectory into such an orbit. In principle, the greater part of the velocity change could be effected by atmospheric breaking in a skipout maneuver, and subsequent minor (≤4000 fps) propulsive deboosting, which would result in considerable (∿70%) savings in weight. Though at present this approach appears to be of questionable feasibility and marginal reliability, further examination of the problem is required, at least with respect to missions following the first manned encounter which may benefit from prior knowledge and experience.

The other problem concerns the altitude of the spacecraft orbit. Considerations of this probe's communication capability and the desire for long term synoptic observations prescribe for it a lifetime on the order of a terrestrial year. A planetary satellite's lifetime varies, however, approximately as the inverse of the atmospheric density at the satellite's initial altitude. Knowledge of density in the Martian upper atmosphere is, however, still subject to order of magnitude uncertainties. At present, it is only possible to indicate the range of altitudes which may accommodate a year long mission in a circular orbit around Mars. Figure 7 illustrates this problem: it presents both lifetime of an orbiter (dashed curve T_s with values corresponding to the ordinate on the right of the figure) and the range of altitudes (stippled region bounded by the two solid curves with values corresponding to the left ordinate) versus density. Thus, if a lifetime of ∿300 days were desired for the orbiter, the range of altitudes indicated by current atmospheric models for its deployment varies between ∿150 and ∿400 km; the vertical dashed line represents this range.

To obviate repeated propulsion maneuvers for orbit correction, which are both an additional burden in weight and potential failure sources, it is desirable to place the orbiter initially into orbit at the proper altitude. This requires knowledge of conditions in the upper atmosphere. Considerable broadening of this knowledge may be anticipated in the next decade. But in a contingency, data gained from some en route astronomical observations (e.g., stellar occultations)[8] and drag probe results may aid in the optimal deployment of the orbiter.

The geophysical <u>lander</u> and especially the <u>MSSR</u> are relatively heavy probes, having a landed weights of ~1400 lbs and

and $\sim$7000 lbs, respectively. This precludes propulsive deboost, which would require weights of $\sim$10,000 and $\sim$50,000 lbs, respectively, at launch from the MEV. As Figure 8 demonstrates, the alternative to propulsive deboost from high entry velocity is the use of an aeroshell. Even so, reduction of velocity to $\sim$2000 fps at an altitude of $\sim$20,000 ft in the rare Martian atmosphere prescribes entry at a shallow angle, $\sim 19°$ to the horizontal, which imposes a considerable penalty in targeting accuracy, on the order of $\sim$120 km in the down range flight direction at the Mars surface.

But a further look at Figure 8 indicates that additional deboost by a different method is required to provide for soft landing, at a speed of $\sim$5 fps, which appears mandatory for the proper functioning and attitude of the rather complex and delicate instrumentation aboard the MSSR and landers. The use of parachutes is not excluded but is of questionable feasibility on account of the tenuity of the Martian atmosphere, and due to the possible severity of winds which may prevail near the surface of Mars. In absence of quantitative information on this subject, it may be preferable to provide the relatively small velocity change by propulsive means.

The foregoing sections do not exhaust the topic of atmospheric effects on the encounter mission profile, but further elaboration on minor effects would be beyond the scope of this brief survey.

IV. METEOROLOGICAL AND AERONOMICAL EXPERIMENTS IN A 1975 MARTIAN ENCOUNTER MISSION

To provide a clearer perspective of the many experiments in this general area which are included in the proposed mission, these experiments will, in the following, be divided into two broad categories. The term primary experiments will apply to those experiments whose primary purpose is the study of the atmosphere, and which could, in part, be omitted in the hypothetical case that the desired information were available. Backup experiments are experiments or operations which are conducted for other primary purposes but yield information pertinent to the atmosphere.

The experimental equipment itself is also divided into two main classes: remote sensors and direct probes. Direct probes, as defined in this context, are instruments carrying out mostly local in situ measurements of certain parameters, with results amenable to fairly straightforward interpretation. This is the case, for instance, when temperature is measured with a thermometer, or chemical composition is measured with a mass spectrometer. Remote sensing, on the other hand, is generally of wider spatial coverage, but interpretation of its results is to a large extent model dependent and ambiguous. It appears, therefore, desirable that the experimental payload be suitably balanced between remote sensors and direct probes.

A summary of the experimental program in the field of atmospheric studies for a 1975 Martian encounter mission is represented in Tables II and III. The consecutive columns in these tables are addressed respectively to the following questions:

(1) Which probe carries the experiment under consideration?

(2) What type of instrument is used?

(3) Which are the objects under observation in the experiment and the quantities measured?

(4) Which particular problems are attacked by the experiment?

(5) Which aspects of the planetary program are likely to be most affected by the results of the experiment?*

(6) When are the measurements carried out?**

(7) What is the location of the probe carrying the experiment at the time it is conducted?

A number of points in the summary of experiments are in need of elaboration. These will now be elucidated in the order of their appearance in the respective tables.

A variety of astronomical observations will be carried out aboard the manned module, with the 40-inch telescope and accessories, during the month or so bracketing the spacecraft planetary encounter. These observations of Mars are essentially of a kind similar to those conducted in earth-based observations[(5)], such as absorption spectroscopy and polarimetry, as well as stellar light occultation experiments. The relative proximity to the planet offers the following advantages. (1) Both the random variations in "seeing" conditions and calculable effects of the Earth's atmosphere are eliminated. (2) During this time interval centered around encounter with the planet the linear resolution of Martian features with the 40-inch telescope aboard the spacecraft is at

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E denotes return of results of primary significance from an engineering point of view for the present mission; E refers to data useful for subsequent missions; SC denotes data of primarily scientific interest.

**M denotes the time of periapsis of the manned vehicle.

least twice as good as with the largest earth-based telescope. It varies, for instance, in the region of 10μ, between $\sim$100 km at the limits of this time interval and $\sim$5 m at encounter. This offers an opportunity to perform this type of observation with increased spatial resolution. (3) Observations are possible at phase angles unattainable from Earth (and Earth satellites). (4) Occultation measurements from close distance to the planet probe lower regions of the atmosphere than those conducted from Earth.[8]

Though some of the parameters measured by the above described astronomical methods will be studied with other methods, a fair amount of redundancy is desirable for obvious reasons. Moreover, depending on the particular overall mission profile, the above mentioned observations may extend the spatial coverage of the atmosphere in the experimental program.

This reasoning applies also to the remote sensing of atmospheric (and surface) properties with the IR, visual, and UV radiometers, medium resolution spectrometers, and the topside sounder aboard the manned module.

The principal in situ measurement aboard the manned module is a mass spectrometric scan of the upper atmosphere and exosphere, which should yield continuous profiles of density and composition in these atmospheric regions, starting from a lower altitude of $\sim$300 km. This study will shed light on the problem of upper planetary atmospheres and their interface with interplanetary space for the case of a planet which is not screened from the solar wind by a sizable magnetic field. Some of the information gathered in this way should be valuable in the planning of future missions, and especially in the deployment of long lived orbiting probes.

The experimental payload of the aero-drag probes, as well as their expected data return, is quite limited, but they do provide a directly measured profile of the structural parameters of the atmosphere, including temperature (T), pressure (p), density (ρ), and composition (symbolized by partial density (ρ_i) from $\sim$100 km to the surface. The upper part of this altitude range (above $\sim$30 km) is not accessible to either direct or remote measurements by any of the other probes*, except during their descent phase. Knowledge about the region from 0-30 km will be derived mainly from multiple RF occultation and sounding rockets.

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*In the Earth's atmosphere this is typically the region probed by meteorological rockets.

Aero-drag probe data at a number of selected locations offer the possibility of calibration of remote measurements, which is in accordance with the desired balance between direct probes and remote sensors.

Of the primary atmospheric experiments carried aboard the orbiter, the most prominent is the topside sounder. It will furnish ionospheric data supplementing those derived from RF occultation and extending them to very broad spatial coverage. These data may possibly aid in the far future in facilitating radio communication between distant manned stations on the planet's surface.

The role of the weather stations associated with the MSSR vehicle and the landers is completely analogous to terrestrial weather stations, and is not in need of further elaboration. It should be noted that local wind measurements are included in the proposed operation of these stations, which are measurements important with respect to landing of large manned modules in the future. Apart from the conventional instrumentation typical of weather stations, a number of low altitude ($\sim$30 km) meteorological rockets will be launched from these sites, to provide further direct data on this atmospheric region.

In the category of secondary experiments the following are the most significant:

(1) radiometry and multispectral photography from the manned module and the orbiter will provide a fairly complete scan of Martian surface temperatures;

(2) cloud imagery with these instruments will give insight into the gross atmospheric circulation pattern of Mars;

(3) multiple RF occultation of the orbiter[9] will yield a large number (on the order of 10^4) of local profiles of the lower atmospheric and the ionospheric density; also some data on the density of the upper atmosphere will be derived from orbital decay of this probe.

V. SUMMARY

In the foregoing section a broad program for the study of the Martian atmosphere in the framework of a 1975 planetary encounter mission has been presented. It may be considered a rather comprehensive attack on the problems of both scientific and technological interest allied with these aspects of Martian exploration.

Its comprehensiveness as well as some inevitable deficiencies are illustrated in Table IV. This table reviews the totality of experiments from the point of view of the problem areas studied in the mission and their coverage by the various experiments. Inspection of this table combined with Tables II and III reveals that successful completion of the program outlined should yield knowledge of the following areas:

(1) surface temperatures over most of the planet and during different seasons;

(2) structure of the lower atmosphere (up to ∿30 km) over a large portion of the planet and during different seasons;

(3) structure of the ionosphere over a large portion of the planet and during different seasons;

(4) profiles of the structure of the sensible atmosphere (0-100 km) at a number of selected locations;

(5) long term meteorological conditions at selected locations on the ground;

(6) some data on the structure of the upper atmosphere and exosphere; and

(7) large scale circulation patterns of the Martian atmosphere.

As may be seen, the only region of the atmosphere which is not extensively investigated is the region between ∿30 and ∿100 km Exploration of this region is, however, also beset with great difficulties in the terrestrial atmosphere.

Figure 9 further illustrates in more detail the impact of the expected data return. This figure is the post-mission counterpart of Figure 1 and shows schematically the status of information on the atmospheric density and temperature which should ensue from a successful mission. Similar figures could be constructed for other parameters. The striking contrast between Figure 9 and Figure 1 lends support to the statement made at the beginning of this paper that the mission considered here should yield a firm basis for the knowledge of the Martian atmosphere.

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Attachments
  Tables I - IV
  Figures 1 - 9

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(1) Thompson, W. B. et al, "Experiment Payloads for a Manned Mars Flyby Mission," Bellcomm TR-67-233-1, May 15, 1967.

(2) Sinton, N. M. and J. Strong, Astrophysical Journal, Vol. 131, p. 459, 1960.

(3) Kliore, A. et al, Science, Vol. 149, p. 1243, 1965.

(4) Fjeldbo, G. et al, Science, Vol. 153, p. 1522, 1966.

(5) Liwshitz, M., "A Critical Look at the Martian Atmosphere," Bellcomm Memorandum for File, October, 1966.

(6) "A Feasibility Study of an Experiment for Determining the Properties of the Mars Atmosphere," AVSSD-0047-66-RR, AVCO Corp., Lowell, Mass., 1966.

(7) Roberts, L., Astronautics and Aeronautics, p. 23, October, 1966.

(8) Weissberg, H. L., "The Study of Planetary Atmospheres by Stellar Occultation," Memorandum RM-3279-JPL, The Rand Corp., Santa Monica, Calif., 1962.

(9) Kliore, A. and D. A. Tito, "Radio Occultation Investigations of the Atmosphere of Mars," AIAA/AAS Stepping Stones to Mars Meeting, AIAA, New York, 1966.

TABLE I - EFFECT OF MARTIAN ATMOSPHERE ON PROBE DESIGN

PROBE	AREAS AFFECTED	PROPOSED SOLUTION
DRAG PROBE	DECELERATION, COMMUNICATION TIME	HIGH DRAG BODY M/C_DA=0.1-0.2 SLUGS/FT^2
ORBITER	DEBOOST INTO ORBIT, LIFETIME	PROPULSIVE DEBOOST ADVANCE PROBING OF ATMOSPHERE WITH DRAG PROBE
MSSR	DEBOOST, SOFT LANDING	ATMOSPHERIC BREAKING WITH AEROSHELL, M/C_DA=0.7 SLUGS/FT^2; SHALLOW ENTRY ANGLE, -19°, PROPULSIVE TERMINAL MANEUVER

TABLE II - PRIMARY EXPERIMENTS

PROBE	TYPE OF EXPERIMENT	OBJECT OF MEASUREMENT	PURPOSE	BENEFICIARY	TIME	DISTANCE (KM)
I. MEV	TELESCOPE & ACCESSORIES	STELLAR OCCULTATION, SPECTROSCOPIC SCAN	ATMOSPHERIC STRUCTURE, MINOR COMPONENTS	E,SC,E*	(M-2 weeks)-(M+2 weeks)	10^7-3x10^4
	OPTICAL & RADIO SENSORS	ATMOSPHERIC SCATTERING & POLARIZATION	ATMOSPHERIC STRUCTURE, DISTRIBUTION OF AEROSOLS	SC,E*	(M-1 hour)-(M+1 hour)	$3x10^4-3x10^2$
	COMPOSITION PROBE	PARTIAL DENSITIES IN UPPER ATMOSPHERE	COMPOSITION AND STRUCTURE OF EXOSPHERE	SC,E*	AS ABOVE	AS ABOVE
II. DRAG PROBE	ACCELEROMETERS, COMPOSITION PROBES, THERMODYNAMIC PROBES	TOTAL DENSITY PROFILE, PARTIAL DENSITIES, TEMPERATURE, PRESSURE	ENTRY CONDITIONS, HEATING, TARGETING OF IV,V; ORBIT OF III	E,SC	M-12 hours	120-0
III. ORBITER PROBE	OPTICAL & RADIO EMISSION SENSORS; TOPSIDE SOUNDER	SURFACE TEMPERATURE SCAN; IONOSPHERIC DENSITY	SYNOPTIC SURFACE TEMPERATURE SURVEY; IONOSPHERIC STRUCTURE	SC,E*	M-(M+1 year)	300

TABLE II - PRIMARY EXPERIMENTS (Continued)

PROBE	TYPE OF EXPERIMENT	OBJECT OF MEASUREMENT	PURPOSE	BENE-FICIARY	TIME	DISTANCE (KM)
IV. M.S.S.R.	AEROSOL SAM-PLER, WEATHER STATION, COMPOSITION PROBE; BOTTOMSIDE SOUNDER	AEROSOLS NEAR SURFACE, TEMPERATURE, PRESSURE, WIND VELOCITY, HUMID-ITY, PARTIAL DENSI-TIES; IONOSPHERIC DENSITY	LONG TERM METEOROLOGY, SEASONAL CHANGES, LOWER ATMOSPHERE COMPOSITION; IONOSPHERIC STRUC-TURE & DYNAMICS	SC,E*	M-(M+2 years)	0
V. LANDER	AS ABOVE (MINUS AEROSOL SAMPLER)	AS ABOVE (MINUS AEROSOLS)	AS ABOVE	AS ABOVE	AS ABOVE	0
VI. SOUNDING ROCKETS	THERMODYNAMIC PROBES	TEMPERATURE, PRESSURE	METEOROLOGY	E*,SC	M+K months k=1,2...10	0-30

TABLE III - BACK-UP EXPERIMENTS

PROBE	TYPE OF EXPERIMENT	OBJECT OF MEASUREMENT	PURPOSE	BENEFICIARY	TIME	DISTANCE (KM)
I. MEV	16" TELESCOPE & CAMERAS, RADIO SENSORS	CLOUDS, SURFACE TEMPERATURE	ATMOSPHERIC CIRCULATION ATMOSPHERIC BOUNDARY	E*,SC	(M-1 hour- M+1 hour)	$3x10^4$-$3x10^2$
III. ORBITER	HIGH RESOLUTION FILM CAMERA, TV CAMERA	CLOUDS & SURFACE	BROAD SPATIAL COVERAGE OF ABOVE	E*,SC	(M-4 hours)-(M+1 year)	300
	REPEATED RADIO OCCULTATION	ATMOSPHERIC & IONOSPHERIC STRUCTURE	SPATIAL & TEMPORAL VARIATION OF ATMOSPHERE	E*,SC	AS ABOVE	300
IV. M.S.S.R.	HEAT FLOW EXPERIMENT	SURFACE HEAT CONDUCTION	INTERACTION OF SURFACE AND ATMOSPHERE	SC,E*	M-M+2 years	0
	FACSIMILE CAMERA	SKY	LOCAL SKY CONDITIONS	SC,E*	AS ABOVE	0
V. LANDER		AS IN IV				

TABLE IV - COVERAGE OF ATMOSPHERIC EXPERIMENTS

PROBLEM AREA	PROBE	TYPE OF EXPERIMENT
STRUCTURE OF UPPER ATMOSPHERE AND EXOSPHERE	MEV, ORBITER	MASS SPECTROMETRY, ORBITER SATELLITE DRAG
IONOSPHERIC STRUCTURE	MEV, ORBITER, MSSR, LANDER	MASS SPECTROMETRY, TOPSIDE SOUNDER, BOTTOMSIDE SOUNDERS, RF OCCULTATION
STRUCTURE OF MIDDLE ATMOSPHERE (30-100 KM)	DRAG PROBE	MASS SPECTROMETER, RAM SPECTROMETER, ACCELEROMETERS
STRUCTURE OF LOWER ATMOSPHERE ($0<Z\leq 30$ KM)	MEV, DRAG PROBE, ORBITER, SOUNDING ROCKETS	SPECTROSCOPY AND POLARIMETRY WITH TELESCOPE AND ACCESSORIES, THERMODYNAMIC PROBES, MASS SPECTROMETRY, RF OCCULTATION
SURFACE TEMPERATURE	MEV, ORBITER, MSSR AND LANDER WEATHER STATIONS	RADIOMETERS, THERMODYNAMIC PROBES
ATMOSPHERIC CONDITIONS NEAR SURFACE	MSSR AND LANDER WEATHER STATIONS	THERMODYNAMIC PROBES, ANEMOMETER, FACSIMILE CAMERA, GAS CHROMATOGRAPHY
GENERAL CIRCULATION	ORBITER, MSSR, LANDER, MEV	CLOUD PHOTOGRAPHY

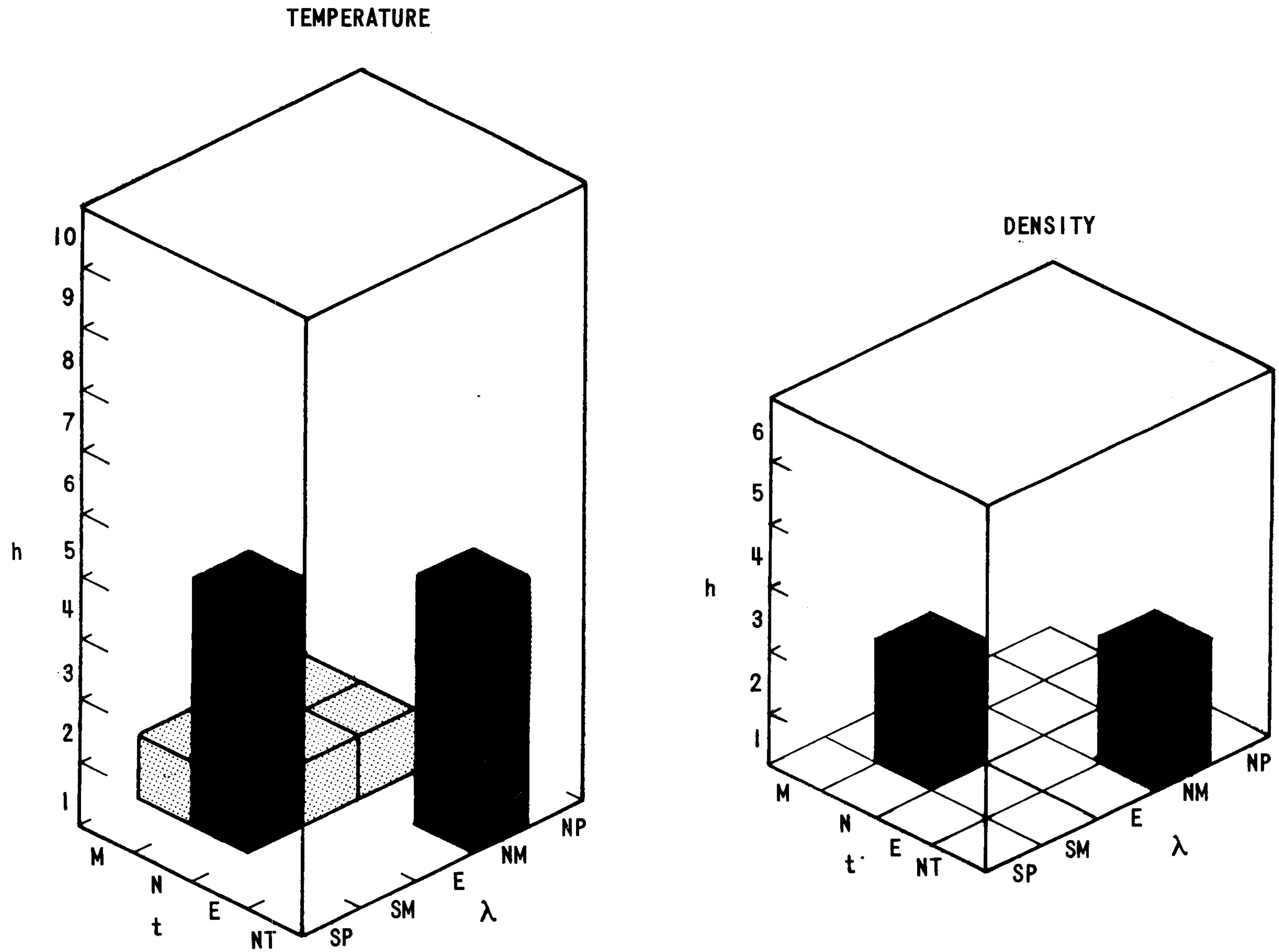

FIGURE I - PRESENT KNOWLEDGE OF MARTIAN ATMOSPHERIC PARAMETERS

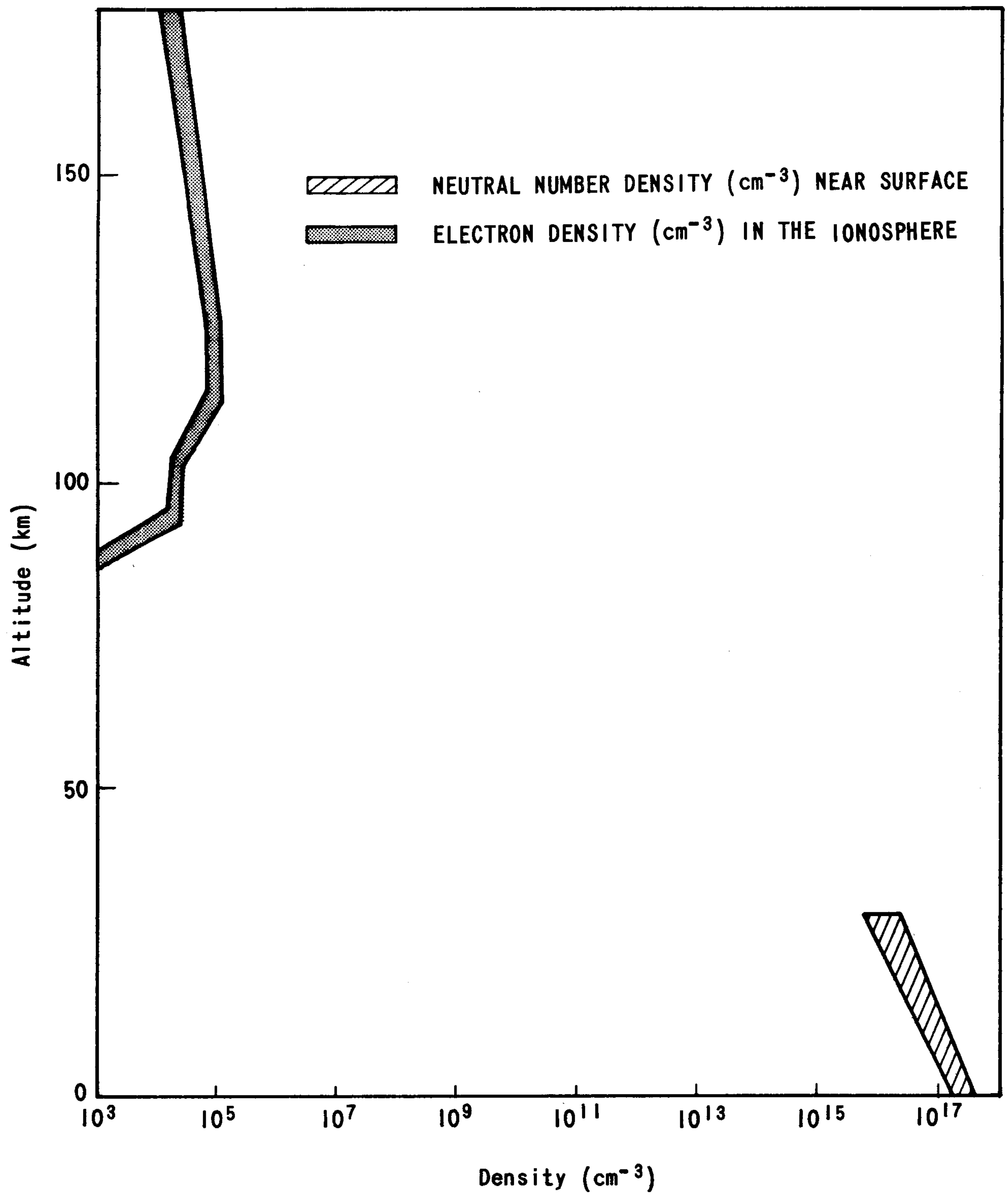

FIGURE 2 - RESULTS OF MARINER IV

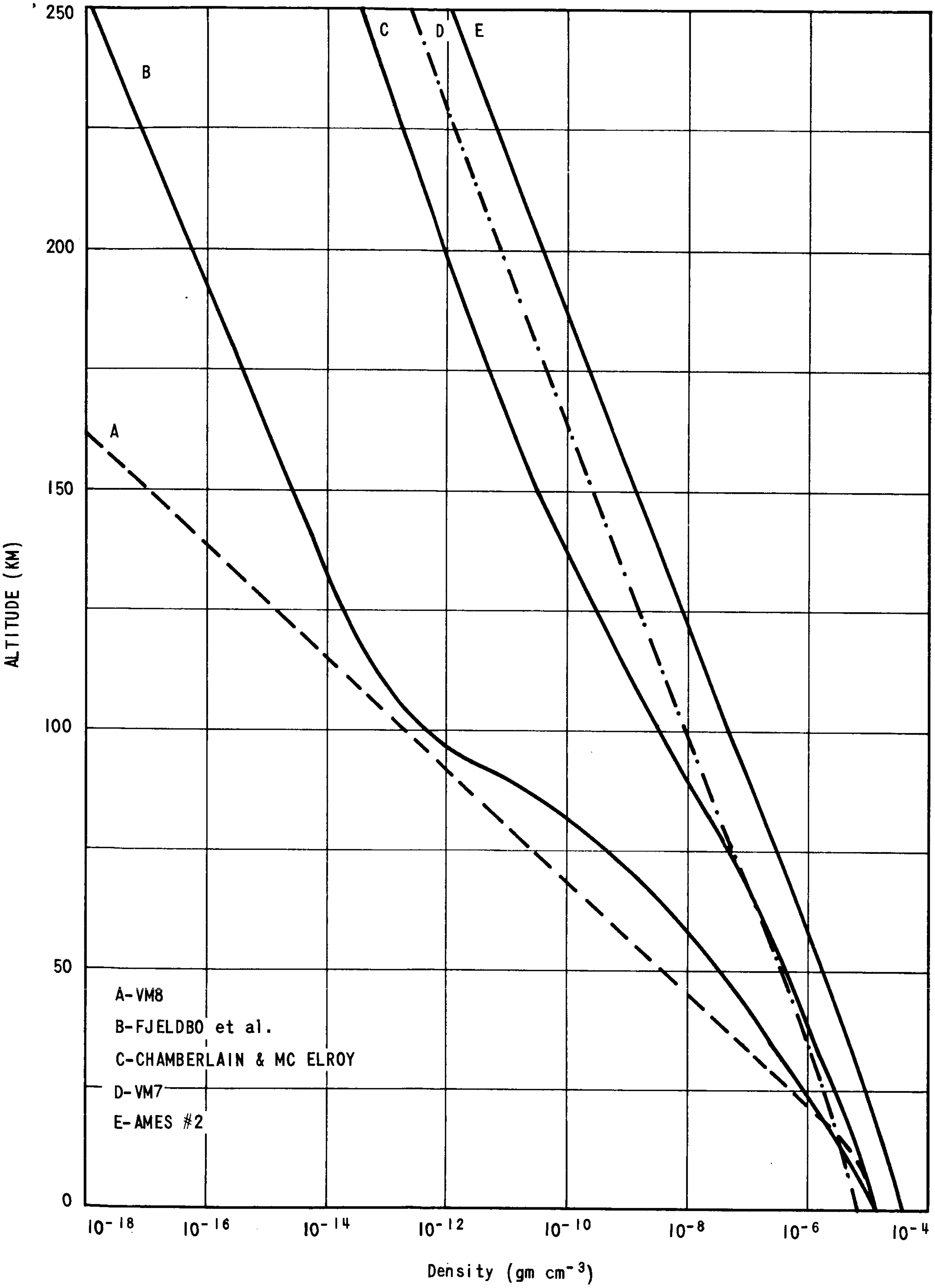

FIGURE 3 - DENSITY PROFILE IN THE MARTIAN ATMOSPHERE

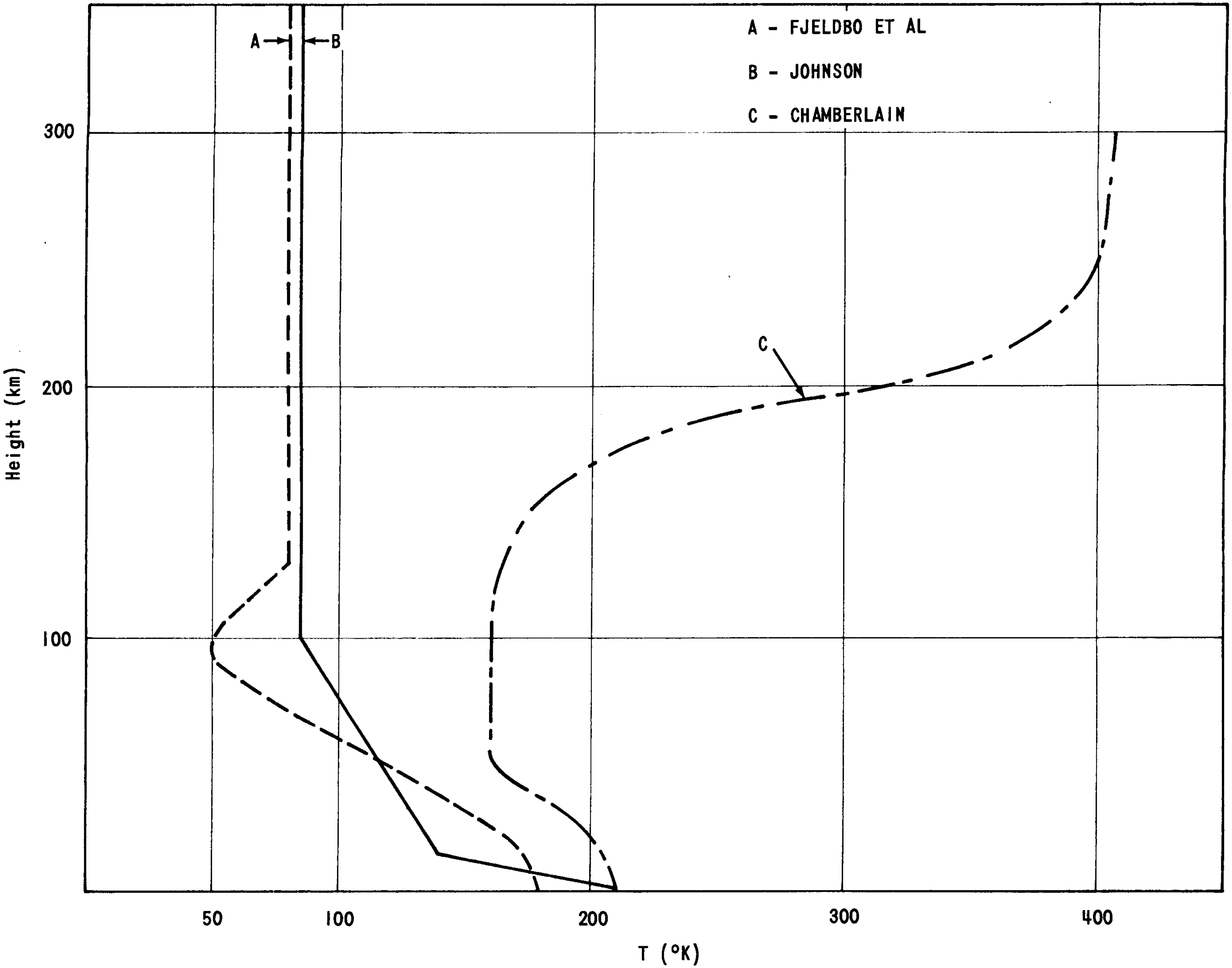

FIGURE 4 - MODELS OF MARTIAN TEMPERATURE PROFILE

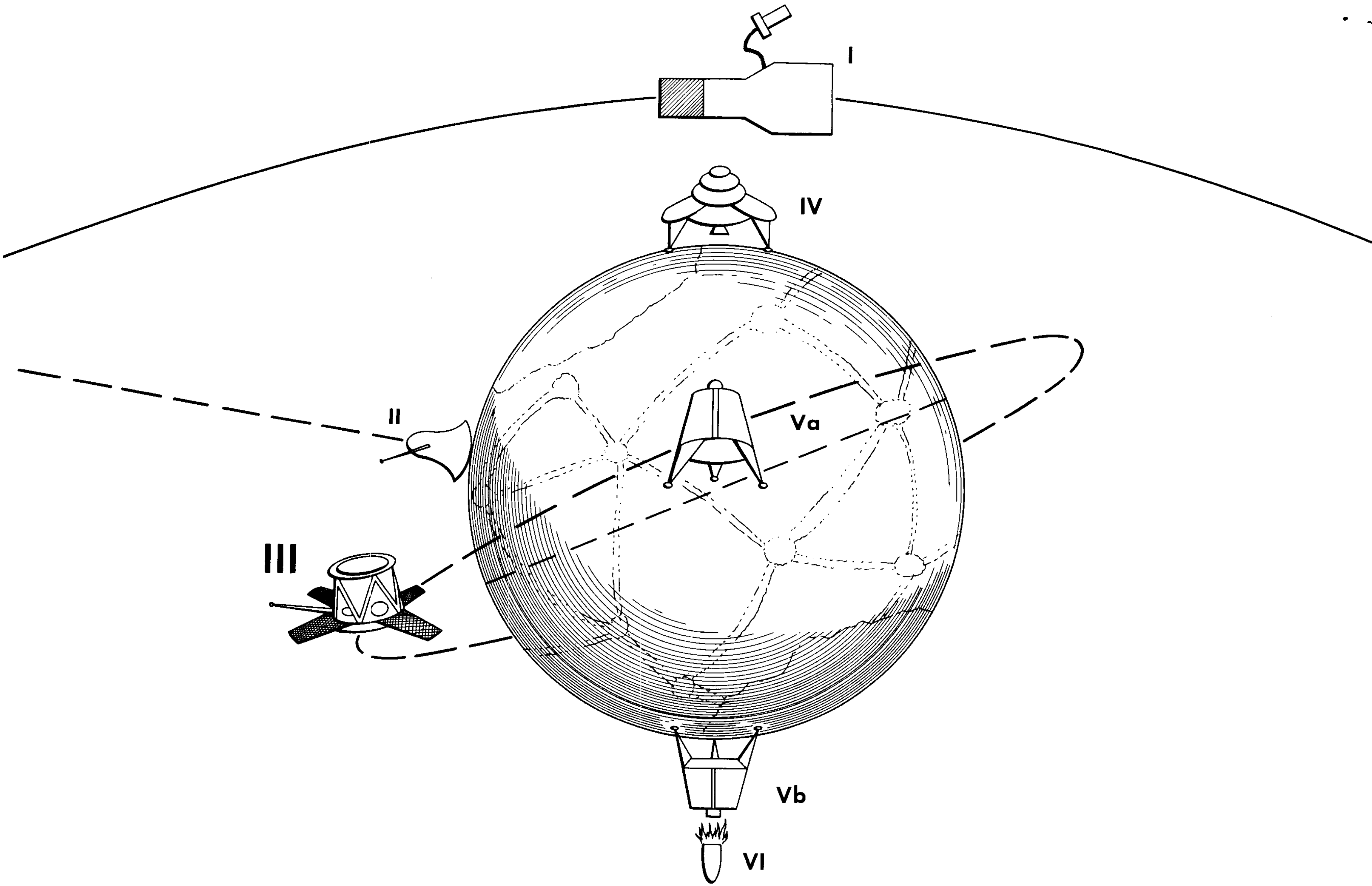

FIGURE 5 — COMPOSITE SKETCH OF MARTIAN ENCOUNTER MISSION

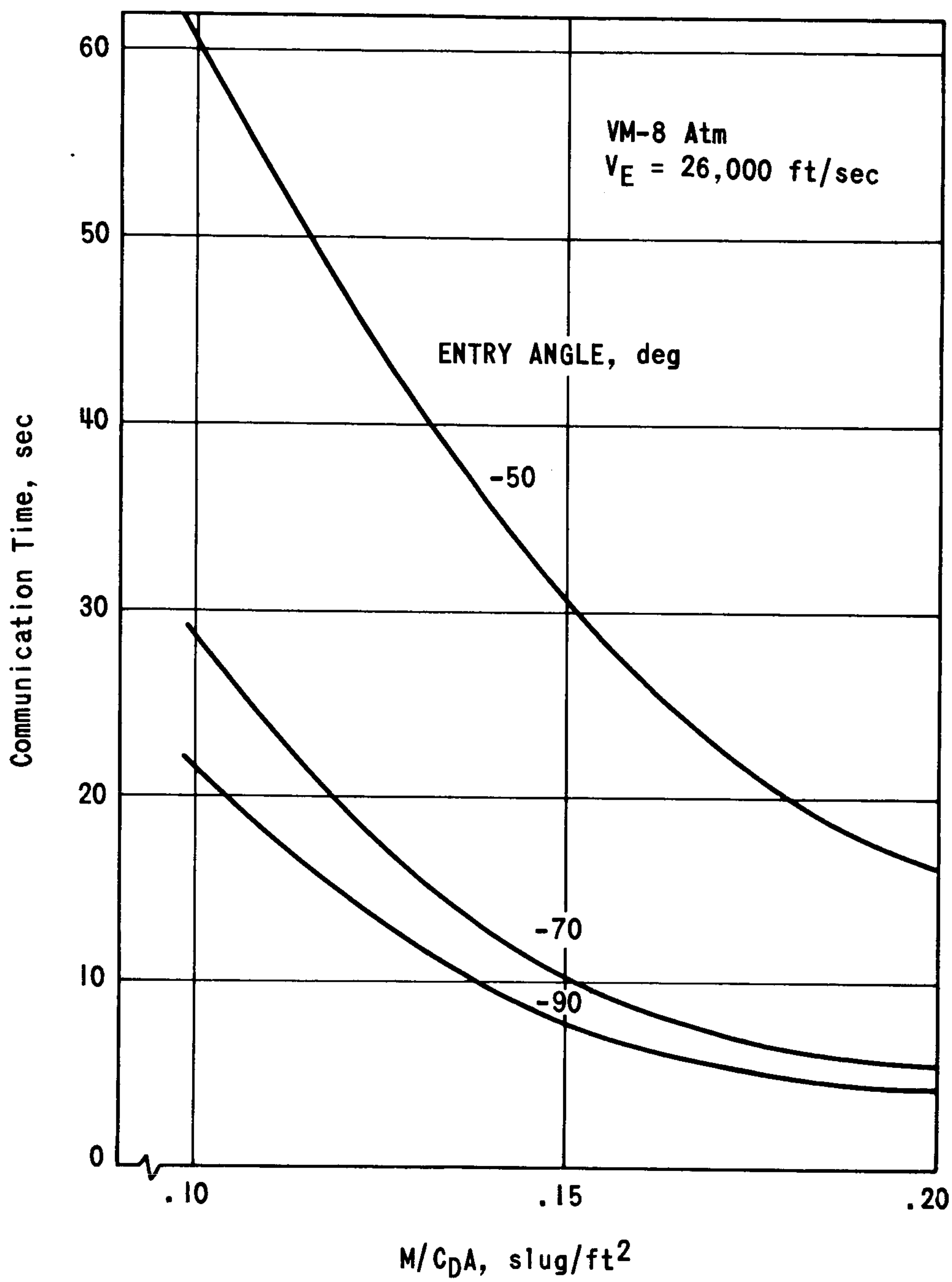

FIGURE 6 - AVAILABLE COMMUNICATIONS TIME (TIME FROM 10,000 FT/SEC VELOCITY TO IMPACT)

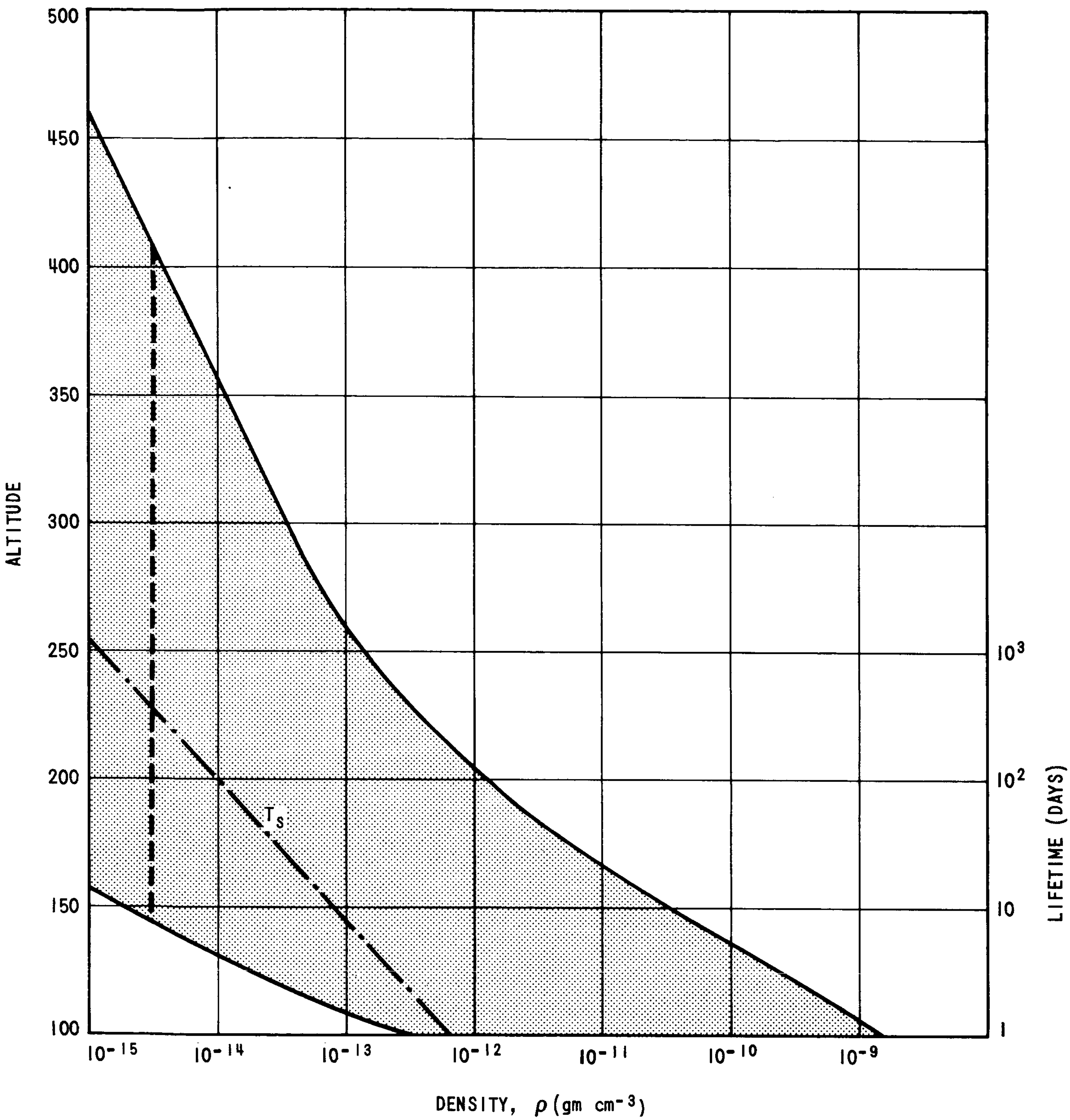

FIGURE 7 - RANGE OF ALTITUDES AND SATELLITE LIFETIME, T_S, VS. DENSITY

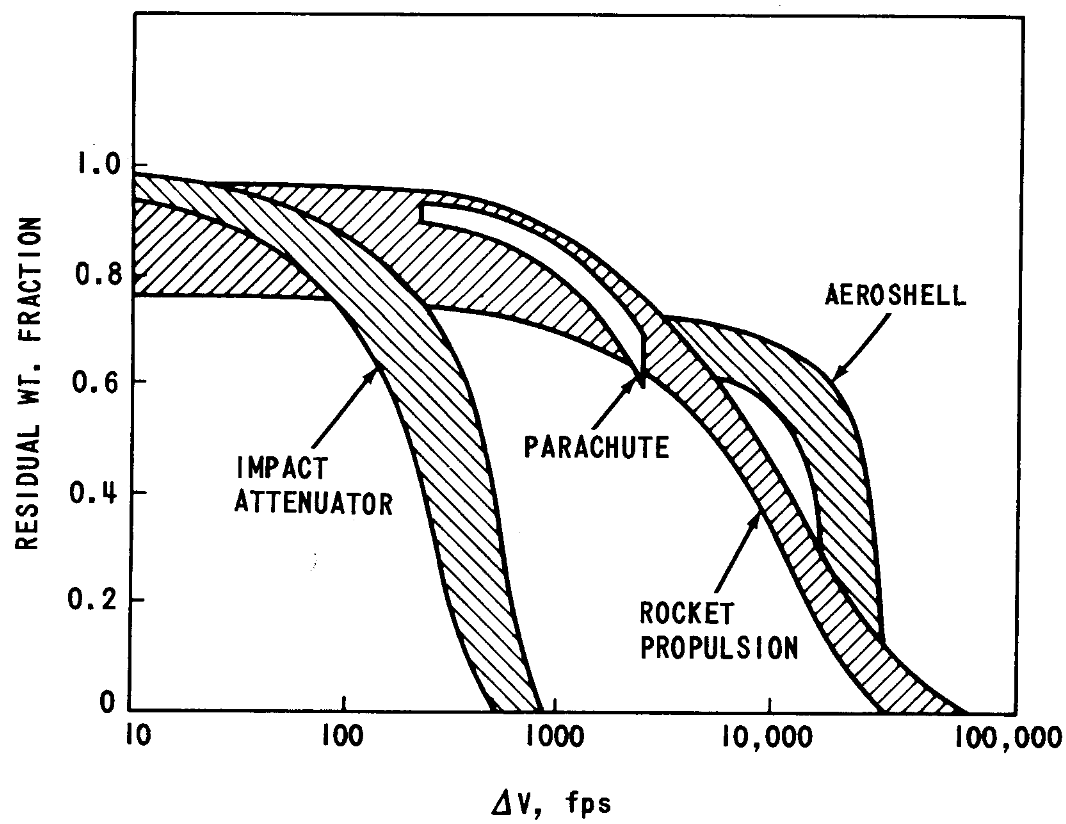

FIGURE 8 - DECELERATOR PERFORMANCE-A RULE OF THUMB (R.P. THOMPSON)

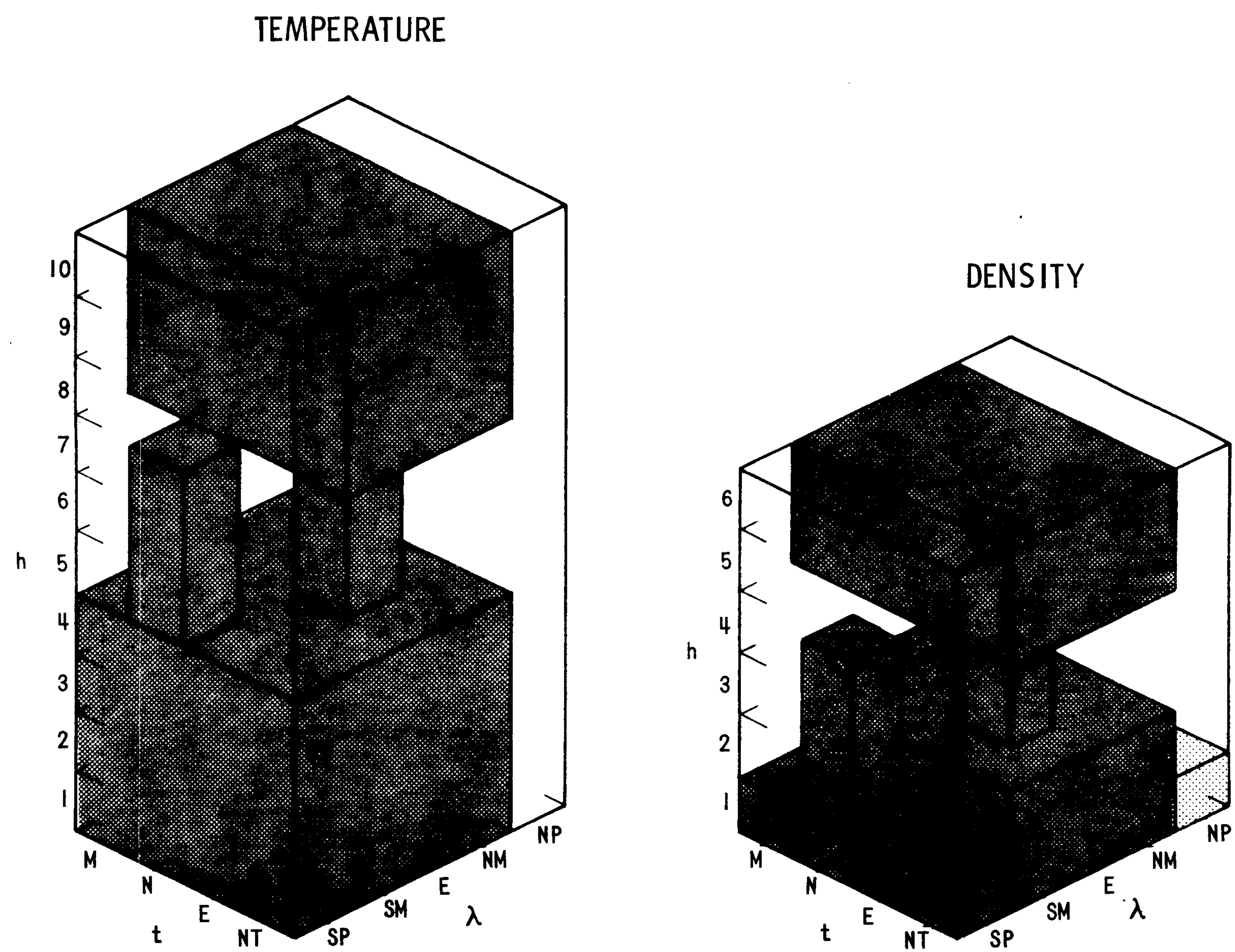

FIGURE 9 - EXPECTED KNOWLEDGE OF MARTIAN ATMOSPHERIC PARAMETERS

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